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Experiments with the reaction of wheat varieties to Puccinia glumarum.

by G. Gassner and W. Straib.

Phytopathologische Zeitschrift, Vol I, No. 3, 1929, pp 215-255. (Only designated portions have been translated).

Introduction.

Tests on the susceptibility of the various wheat varieties to stripe rust have been conducted in diverse places, in recognition of the great practical significance of this type of rust, thus in Sweden by Eriksson and Henning, Nilsson-Ehle, Henning, in Germany among others by Hiltner, Kirchner, Muller and Molz, Lang, Schaffnit and Rump, Schroder, Bonne, in Russia by Vavilov, in France by Foex, Beauverie, Deprez, in England by Marryat, in Finland by Pesola, in North America by Hungerford and Owens (literature on page 256).

Almost without exception these observations represent comparative field tests. In many respects the testing of species in the field is beset by short-comings. For one, the occurrence of rust is usually uneven through the years, making direct comparison of observations quite difficult; similarly, the local differences in the occurrence of rust often exert disturbing influences. Thus we were able to observe, during an inspection of the variant tests of the German-Swedish Seed Growing Association at Derenburg last year, that stripe rust occurred only in those parcels to an important degree in whose proximity it had spent the winter, while the infection of the more distant beds or strips occurred so late that the varieties sowed here were almost free of rust. Therefore, comparative field tests seem to acceptable only if sufficient rust spores are present in the air due to general prevalence of Puccinia glumarum, in order to make the possibility of infection uniform and favorable.

There is little doubt that the contradictions repeatedly found in the literature, concerning the effect of stripe rust on the individual varieties may at least partly be ascribed to the just mentioned sources of error in the field tests; on the other hand it does not seem plausible to explain all contradictions in this manner. It is rather to be expected that the pertinent susceptibility is dependent in a different manner on exterior factors, especially those of a climatic character, or that stripe rust, similarly to other rust types, may be subdivided into subordinated forms or strains which manifest diverse geographic distribution and can infect the individual variants to an uneven degree. The influence of external factors and the existence of rust strains naturally cannot be clarified in the field, or only inadequately so, forcing to resort to complete laboratory tests or greenhouse experiments in addition to field tests, when exploring varieties. Results of such tests, in which the reaction of the varieties to stripe rust is tested by means of artificial infection in the greenhouse, under uniform or exactly controlled conditions, are lacking to date, other than those of Hungerford; besides, the experimental basis of Hungerford's work does not seem adequately firmed and clarified, as we shall show later, in order to solve the difficult problem of varietal susceptibility to stripe rust.

In ~~our own~~ tests first consideration went to the examination of the varietal reaction against stripe rust, ~~more precisely~~ wheat stripe rust, Puccinia glumarum f. sp. Tritici, under the most uniform conditions possible in the greenhouse, and also correspondingly to consider the influence of external factors thereby. We did not plan to explore the possible existence of biotypes; on the contrary, we limited ourselves to testing the varieties with an available pure line of stripe rust, which was obtained by repeated inoculation from separately positioned, just opening pustules of isolated plants. The starting material came from a rust-containing wheat plant of the seed-growing farm Strube at Schlanstedt, while our previous tests (Gassner and Straib, 14) had utilized spore material from the test field Braunschweig-Gliesmarode. As far as we can tell, no differences in infectious effect is evident in the spore material obtained from Gliesmarode and Schlanstedt.

Besides greenhouse testing of the variants, field observations were effected in order to clarify the basic question to which extent the results of greenhouse experiments would be parallel to rust occurrence in the field, and how much practical value the first would have for the farmer and grower. We were able to accomplish systematic observations of rust in connection with varietal behavior in the field during the past years on our test field at Braunschweig-Gliesmarode and on the seed-growing farm Strube-Schlanstedt, as well as by occasional observations at diverse places, among them Svalof (Sweden). In the following we shall consider above all the observations made at Schlanstedt, since they are the most detailed and because the prevalence of stripe rust was especially regular and marked. We take this opportunity to express our appreciation to the firm of Strube-Schlanstedt for its generous spirit of assistance with which it granted the use of its varietal tests and its stands of wheat assortments for our purposes and thus simplified our work in every respect.

The execution of varietal infection tests and the evaluation of rust manifestations.

No other type of grain rust is as dependent on the consideration of all accessory conditions for success in artificial infection as stripe rust. For this reason the exact knowledge of infective conditions is an indispensable preliminary condition for the testing of the various varieties in their reaction to stripe rust in comparative infective tests. Therefore we have first undertaken the necessary clarification of the infective conditions and have reported on them elsewhere last year (Gassner and Straib, 14).

Even the cultivation of spores requires special skill, either a preliminary treatment of the plant material or a special technique of inoculation, since the wax layer adhering to the leaves spoils the infection result. The wax layer may be removed by rubbing between the fingers, which then can be inoculated at will; it is sufficient, however, to apply the spore material (suspended in 1/10 percentual agar) by means of a cotton swab immediately to the upper side of the leaves and to remove the wax layer by repeated rubbing. In the course of the comparative varietal tests to be described below we limited ourselves exclusively to the latter method. Of course this technique of inoculation as well as the removal of the wax layer by rubbing between the fingers causes the disappearance of possibly existing differences in the composition of this layer in the several varieties, whereby a possible source of error may be added. This handicap had

to be accepted for the time being, since attempts at artificial infection otherwise do not succeed with the required effectiveness. According to our conclusions the effect of rust on the varieties is not greatly influenced by the chosen method of inoculation.

Successful infection also depends on the amount of applied spores. If the same varieties are inoculated once with large, once with small amounts of spores, the latter generally show an irregular involvement with rust. In order to avoid false conclusions the spore amount must therefore be large enough. Adjustment of spore concentrations was done colorimetrically. The strength of the substance was chosen in such a way that the cotton swab used for inoculation showed a uniformly yellow color.

After inoculation the plants must be kept for 2-3 days at full exposure in a steam-saturated room; the pots with the test plants on moist ground peat, in a manner previously recommended, are immediately after inoculation covered with a light bell jar for 3 days. Even after removal of the jars adequate moisture must be maintained by moistening of the ground peat, in order to further optimal conditions for pustule formation.

The significance of sufficient light has just been mentioned briefly; tests during the dark winter months are to be evaluated with caution and, if no additional artificial light is utilized, are only usable if clear weather guarantees the nutritional conditions of the test plants. In winter one should count on extending the duration of incubation. During the summer months the vailable light is always so strong that even stronger shading, up to about 50%, may be utilized without harm.

Special consideration must be given to temperature conditions. We have previously (Gassner and Straib, 14) stressed that temperatures above 20°C should be avoided if possible, since the infection results are otherwise less favorable and more uncertain. The varietal tests recounted in the next chapter were accomplished under temperatures which did not exceed this limit or did so only immaterially. Certain fluctuations were inevitable considering the scope of the tests, although the greenhouses available were equipped with air conditioning, in order to make them usable even during the warm season. In order to facilitate the evaluation of test results, the temperatures prevalent during the various test runs are also given. Moreover, the significance of the temperature for successful infection and for varietal behavior will be discussed in more detail later.

In the infective trials with various types of grain, germinal plants were used, whose first leaf was always inoculated at the time of the second leaf's appearance. During cultivation of the plants scheduled for testing no special considerations are necessary; care should be taken however to see that the pots are equipped with garden soil uniformly rich in nutrition, as especially lack of nitrogen may cause distortions in rust formation and infection results due to increased chlorosis.

On the other hand, particular attention should be devoted to the type of spore material and its cultivation. We have already stated in our earlier papers on the infective conditions of Puccinia glumarum in connection with

highly susceptible varieties, that only fresh spore material may be used, preferably not grown at high temperatures. According to the examinations made by Becker (3) published in the meantime, even stored spore material may be used, provided it had been kept at sufficiently low a temperature and not too high a humidity. As for ourselves, we avoided the storing of spore material because the amounts meeded for our experiments were too large. Thus only fresh spores were used, cultivated accordingly. During tests in late summer it was unfortunately not always possible to maintain the necessary temperature of 16°C or lower during cultivation. Temperatures above 20°C were avoided, however, as this would have meant a severe curtailment of infective ability on the part of the spores.

Since our previous tests with highly susceptible varieties had already shown that successful infection is equally dependent on the cultural conditions of the spore material, we were forced to assume from the start that comparative infective tests with diverse wheat varieties would only lead to unequivocal results if fully infectious spore materials are used. While utilization of weakened spore material in connection with susceptible varieties does lead to normal, if weaker, infective success, the difference in results, when using weakened spore material in connection with resistant varieties is such that the tests become worthless. Fig. 1 shows tests with Svalofs Panzerweizen III in which, with otherwise exactly duplicated test execution as to light, temperature and humidity conditions, the leaves on the left were inoculated with fresh spore material from the hot house (18-22°C), the leaves on the right with fresh spore material from the cold house (8-14°C). Subsequent cultivation was effected at temperatures between 8 and 14°C. While the right-hand leaves show considerable pustule formation within extensive chlorotic spots, the plants infected with material from the hot house reveal only weaker chlorotic spots with absent or quite minimal pustule formation. Similar findings were obtained from other varieties, therefore in all varietal tests the virulence of the spores must be controlled. Appropriately, each test run should utilize control plants whose reaction to virulent spores is known. As control varieties we recommend the simultaneous utilization of one susceptible and one moderately resistant variety, i.e. at temperatures of 18-20°C e.g. Beseler Dickkopf III as susceptible and Salzmunder Standard as moderately resistant variety. The controls are inoculated simultaneously with the varieties to be tested; only those test series seem unequivocal which reveal the highest infection type on the susceptible variety and the characteristic appearance under the pertinent test conditions on the resistant variety. Furthermore, the simultaneous utilization of control varieties is necessary because slight alterations in the infection's appearance may occur if fluctuations should happen in the normal test conditions, light, temperature and humidity.

The question of test duration in comparative varietal experiments is determined first of all by the time of incubation which for stripe rust lies between 12 and 20 days, depending on thermal conditions. At 14-20°C the duration is almost uniformly 12 days, at 10-12°C it extends to 15-17 days. These values apply to favorable conditions of exposure and to susceptible varieties. In tests during the short winter days and by utilization of resistant varieties delays of several days are noted. In both cases test durations should be extended in oder to recognize possible later changes in the rust appearance or, if only discoloration of the leaf has occurred, a subsequent formation of pustules.

Comparative infective trials in the greenhouse are accomplished with germinal plants, for obvious reasons, as already mentioned. Here the arrangement of spore deposits of Uredo glumarum is not typically striped, as in older plants, but irregularly scattered. Differences in comparison to other rust types exist to this extent that discoloration, if any, is not limited to the proximity and surrounding areas of the pustules or the locale of infection, but usually extends over large parts of the leaf. Due to this fact we cannot simply apply the infection types formulated for other rust types to stripe rust.

Credit for the utilization of the infection type as a yardstick of infection degree is due primarily to American researchers, especially Stakman and his pupils (30,31). The data from these authors cover primarily Puccinia graminis, P. triticina, and P. coronifera, while stripe rust, since it does not affect North America extensively, found consideration later by Hungerford and Owens (18). Hungerford, however, has almost exclusively used the description utilized for the other rust types in his characterization of the different kinds of stripe rust. As for ourselves, we do not deem such a direct transposition feasible, in view of the frequent deviation in the appearance of stripe rust, which is the reason why we list a precise description of the infection type of stripe rust by way of Fig. 2 and 3, in which we also choose the designation 0-4 and the prefix i in case of total immunity.

Recently colored plates of infection types of stripe rust were reproduced by Gassner in the Handbuch der Landwirtschaft, Vol II, plate 4. Infection types 0, 1, 2 and 4 depicted there correspond with the following description, type 3 has not been reproduced well, however. It should reveal more marked chlorosis and more numerous pustules in the color plate. We refer therefore to numbers 12-14 of Fig. 3, especially as concerns type 3.

The various infection types of Puccinia glumarum can be characterized as follows:

i - immune. Leaf completely healthy, no discolorations.

0 - highly resistant. No pustule formation, but necrotic spots and at times death of the whole leaf.

1.- very resistant. A few very small isolated pustules in generally extensive necrotic spots.

2 - moderately resistant. Weak pustule formation. Pustules usually small within heavier or lighter necrotic spots.

3.- moderately susceptible. Medium to severe pustule affliction within chlorotic-necrotic discoloration of the leaf.

4 - very susceptible. Severe eruptions of pustules uniformly distributed over the leaf, with weak chlorosis at most.

This system of course cannot cover all individual pictures presented in comparative varietal tests in the greenhouse; similar appearances had to be grouped together under the designations 0-4. Infection type 0 either shows

sharply delineated discoloration or a gradual blending with the green and healthy leaf tissue; the necrotizing aspects are not always the same, either. Type 1 differs from type 0 primarily by the occurrence of isolated pustule formation. In type 2 pustule formation is already stronger, but also irregular as yet, in which sometimes a large aggregation of pustules is apparent. Type 3 is always marked by more severe affliction of pustules, the pustules however are situation within chlorotic areas which later necrotize, or, if the pustules are located in the green tissue, extensive necrotic areas are seen between these as yet green tissues. Type 4 represents maximal infective success. We have an exceedingly copious pustule formation either without any chlorosis or with insignificant light discoloration.

Varietal infection tests in the greenhouse.

Tests of stripe rust reaction described here covered a total of 536 varieties and origins. The utilized seed material consisted partly of original seed from the respective grower and is denoted as such with an * in the statistical presentations. The major part of the seeds represented subsequent plantation and emanated from the assortment garden of the firm of Strube-Schlanstedt. A few Spelz, Einkorn and Emmer forms were drawn from the botannical garden of the Agricultural College at Hohenheim. The South American wheat varieties came from the test field at Estanzuela (Uruguay) and were furnished by Dr. Boerger and Dr. Fischer. We should like to express our appreciation to all agencies who supported us with seed,especially to the seed-growing farm of Strube-Schlanstedt.

The representation of the main results is given in the two large tables A and B, listed at the end of the paper in view of the large scope. The individual varieties and origins are alphabetically ordered without regard for their type and race classification under the various Triticum forms. Only one division has been made, in that table A contains winter varieties, table B the summer varieties. For each variety and origin as well as for each test the number of observed infection types was counted and listed.

Since the germinal behavior of the available varieties was erratic, and since only relatively small amounts of seed were available of each variety, it was not possible to resort to the same number of plants in each test. On the other hand, it seemed practical to undertake repetitions with varieties of which unlimited amounts of seed were available.

In view of the large scope of our tests the simultaneous examination of all varieties was, of course, impossible. Therefore the tests were conducted in 26 different test groups, of which the first commenced on 27 March 1928. It is true that varietal test results were already available from the summer of 1927 and the winter of 1927/1928, but they were not considered in our summaries since the sources of error were not adequately known at the time of the first tests, resulting in diverse disarray. As the infection result in the case of stripe rust is particularly dependent on external circumstances, as already mentioned, we have reported in table 1 (page 226) not only the test start, but also the average temperatures during the individual test groups. The first column of tables A and B shows the respective test group in shich the variety was tensted, making it feasible to follow a possible relationship between rust

appearance and test conditions, i.e. test start and temperature, for each variety.

The results tabulated at the end of our publication show that it is possible, in the greenhouse, to determine the differences in reaction to rust of the individual varieties. The question of origin and subsequent plantation seems to be of subordinated importance, as revealed by a comparison of tests with original seed and with later growth, since original seed * and subsequent seed showed an identical behavior in respect to rust, and, as far as differences do exist, they do not exceed the irregularities commonly noted. For this reason there is no need to consider the question whether original or secondary seed is involved.

The overwhelming majority of the tested varieties revealed a high susceptibility to Puccinia glumarum. Especially the German varieties as a rule are easily infected.

Resistant forms with a predominant occurrence of infection types 0-2 were found among German as well as foreign varieties. Of the German strains Carstens Dickkopf V, Kraffts Dickkopf, P.S.G. Hertha Weizen and Strubes Neuzuchtung 3186 should be mentioned among others as resistant varieties. The well-known Swedish Svalofs Panzerweizen III also proved to be rather resistant. Highly resistant were the Rote samtige Einkorn, Triticum monococcum var. Hornemannii, and of the foreign varieties, Clovers red.

Of the summer forms, Janetzkis fruher Sommerweizen and Swedish Aurore-Weizen were resistant, even more so Heines fruher Kolben-Sommerweizen. Highly resistant without formation of pustules, but with necrotic spots were Sommer-Igel Weizen as well as Chinese wheat von Remy I and V.

Immune forms in which no infection whatever resulted, i.e. not even necrosis, were not found at all among the German varieties. On the other hand, of the foreign winter forms, Modellweizen, Spaldings prolific and de Crepi were immune.

During an examination of the test results listed in tables A and B it becomes conspicuous that in many test series the same variety has plants with lower as well as higher infection types. Since reports of cleavage in rust susceptibility have been received from several quarters, as recently from Scheibe (28), regarding other types of rust, especially Puccinia triticina, the thought presents itself that cleavage could be involved in the different reaction to stripe rust by plants of the same variety. We can observe such cleavage particularly in the resistant varieties, less so in highly susceptible and immune forms; this conclusion supports the opinion that we are not dealing with impurities of the seed, which naturally could be in the realm of possibility when seed from assortment gardens is involved.

It the assumption is correct that the behavior against stripe rust just mentioned is a manifestation of cleavage, then this cleavage must always occur approximately in the same percentage as is the case, for example, with Puccinia triticina in the cases tested by us. In this respect the repetitions contained at the same time in tables A and B show that we cannot speak of a constant in the cleavage manifestations. Thus, for example, P.S.G. Hertha Weizen in one

test shows 65% type 0, 0% type 1, 25% type 2, 10% type 3, while in the repeat it shows 96% type 0, 4% type 1, 0% type 2, 0% type 3. We must admit that the available statistical material is inadequate for evaluation as to constancy or non-constancy of leavage, since the majority of tests were conducted with but a relatively small number of test plants. Hereby the judging of the respective numerical relations of the various infection types becomes uncertain, especially since the peculiar infective conditions of stripe rust , more than any other type of rust, advise caution in the evaluation of test results.

The question, whether or not manifestations of cleavage in the accepted sense were involved, could therefore be clarified only in those test series, in which by several repetitions the highest possible number of plants were inoculated in precisely the same manner. Most suited for these mass infection trials, as listed in table 2, were above all resistant varieties with a possibility of cleavage as revealed by infection results listed in tables A and B.

Our observations of Carstens Dickkopf V and Strubes Neuzuchtung 3186 are especially detailed. The results show unequivocally that we cannot speak of regular and constant cleavage. In some test series type 3 predominates, in others other infection types or even type i. In this connection it should be noted that corresponding tests were conducted simultaneously with highly susceptible varieties, e.g. Beseler Dickkopf, and that in these control tests only infection type 4 was observed without irregularities.

We must therefore conclude from the results summarized in Table 2 that the occurrence of different infection types does not exclusively represent genuine cleavage, but that in connection with resistant varieties small and inevitable differences in test commencement and execution led to circumstances in which during one test run more plants show a high infection type and during another a greater number of plants show a lower type, or are not infected at all, thus appear to be immune. As we were later able to show that even small differences in temperature can influence the infective success considerably, we are adding, for the purpose of evaluation of results listed in table 2, a summary of test data in table 3, applicable to tests contained in table 2, especially test commencement and temperature. We can see that thermal conditions in the available greenhouses were not absolutely constant, and we must ascribe a certain responsibility for the different test results and cleavage to these differences and other factors. The resistant varieties may be said to be in a labile balance in respect to their receptivity of infection, in which even weak differences in external conditions may elevate or lower the degree of infection.

The reproduction of table 3, above, containing the test commencement date and the thermal conditions for the mass infection tests listed in table 2 should not be interpreted to mean that we can ascribe the differences of the results only to conditions of temperature. Other moments may have intervened just as well, among them weak differences in the virulence of the spores, or the amount of applied spores, further — differences in lighting, possibly even factors of humidity. However, we shall prove in detail in the following chapter that among the factors mentioned above, temperature doubtless plays a very important role.

The significance of temperature for varietal susceptibility to stripe rust.

The cleavage in susceptibility to stripe rust observed in the tests of the preceding chapter reveal a distinct dependency on test conditions to the extent that the numerical relation of cleavage is different in the individual test series. A number of individual observations point to the fact that the temperature differences between the individual test series play an important role in this connection. The thermal data reported simultaneously in the preceding chapter often show only slight differences in temperature between the individual test series, so that it was questionable at first, whether these weak fluctuations really were able to displace the rust susceptibility of the individual varieties to the large extent observed. On the other hand we were able to determine previously (Gassner and Straib, 14) that a small temperature elevation above 20°C lengthens the incubation time and harms the infection result. These observations were made with highly susceptible varieties. It was therefore probable that a small change in temperature would be even more noticeable in connection with resistant varieties, so that at least an important part of the varied rust susceptibility of the same variety noted in the various test series of the foregoing chapter could be ascribed to such relatively small fluctuations in temperature.

The test series discussed in the preceding chapter do not suffice to explain the entire question, since temperature differences cover the entire project in an arbitrary and irregular manner, and also because differences in light and humidity existed during the months in which the tests were conducted. Therefore it follows that conditions in simultaneously started test runs should be varied in such a manner that only temperature differences remain as the variable factor. Certain slight differences in humidity cannot be entirely avoided, however; we shall discuss this later. At this point it suffices to point out that small differences in the relative humidity may be ignored in the present observations, making the results unobjectionable in this respect.

Thermostats which would permit cultivation of the test plants under identical light conditions and exactly constant temperatures, were not available. We were limited to the use of three differently tempered greenhouses which were connected in such a manner that the hot house was linked to the cold house by a connecting or middle house. The temperature in these houses could be held nearly within the desired bounds by constant supervision. This was effected by corresponding regulation of heating, by shading, airing and utilization of the available cooling system of the greenhouses. To be sure, the tests were limited to a season that allowed the use of the ennumerated aids in temperature regulation. First consideration was given the months February to April, especially so since the temperatures were favorable to our tests that year. The summer months were eliminated because the lower temperatures could no longer be obtained; the same applied to the fall. Execution of tests during the winter months proper was avoided in view of frequent inadequacy in light conditions.

On the basis of preliminary tests the execution of the main experiments was planned as follows:

Tests in the hot house: in the first and fourth test runs 20-22°C,
in the others 18-20°C.

Tests in the middle house: 14-16°C.

Tests in the cold house: 8-12°C.

The maintenance of temperature required constant supervision, in that immediate shading or airing was effected at the rise of daylight temperatures or at the appearance of the sun, while the heater was started when external temperatures sank. In spite of this complicated mode of regulating no disturbances occurred during the tests. Table 4 gives a summary of actually maintained temperatures for the duration of testing.

The cultivation of test plants took place regularly in the hothouse after it was found that the initial growing temperature has no effect on the subsequent varietal behavior under different temperatures. Immediately following inoculation the test plants were distributed to the hot house, middle house and cold house with different temperatures. In order to give the tests a secure foundation the number of test plants was set as high as possible. Of the susceptible varieties between 50 and 100 plants were inoculated each time, of the resistant varieties during the first 3 tests about 100 to 400 plants per variety and temperature. Test series IV utilized a smaller number of plants, fluctuating between 33 and 69 per temperature for the resistant strains.

The inoculation, the 3-day long covering of the plants following inoculation, as well as the setting and moistening on ground peat was accomplished in exactly the same manner at all temperatures. The spore material used was completely uniform and taken carefully from cold-grown plants. Other sources of error also were avoided as far as possible, making the tests seem unobjectionable in this respect also. We want to stress this specifically at this point, because the conclusions discussed below are of fundamental importance to the entire question of research of varietal resistance to stripe rust.

Susceptible as well as resistant varieties were tested. We shall dispense with a detailed account of the results obtained with susceptible varieties, since no differences in rust effect were noted at temperatures of 18-20°C, 14-16°C and 8-12°C, unless we consider the extended incubation at 8-12°C compared to 14-20°C. Only when the temperature was increased to 20-22°C (test series I) a slight decrease in infection was noted in the susceptible varieties, tending to reaffirm our previous conclusions (Gassner and Straib, 14).

We shall give more detail to the observations of resistant varieties, because the differences in rust-susceptibility is quite marked here.

All in all, the following wheat varieties were utilized:

Test series I: Heines glatter Teverson
Carstens Dickkopf V
Heines fruher Kolben-Sommerwizen
Kraffts Dickkopf
v. Rumkers fruher Sommerdickkopf
Svalofs Panzerweizen III.

Test series II: Ackermanns Bayernkonig
Heines glatter Teverson
Aurore-Sommerweizen
Heines fruher Kolben-Sommerweizen
v. Rumkers fruher Sommerdickkopf.

Test series III: Strubes Dickkopf
Heines glatter Treverson
Kraffts Dickkopf
v. Rumkers fruher Sommerdickkopf
Svalofs Panzerweizen III.

Test series IV: Ackermanns Bayernkonig
Strubes Dickkopf
Heines glatter Teverson
Lembkes Obotriten
Mettes Schlossweizen
P.S.G. Hertha Weizen
Rimpaus fruher Bastard
Salzmunder Standard
Svalofs Kronenweizen.

The final results of the comparative temperature tests with above wheat varieties are given in tables 5 and 6, table 5 being a summary of test series I-III, while table 6 contains results of test series IV. In view of the larger number of tests in series I-III the results could be calculated as percentages, while we limited ourselves to the ennumeration of actually examined plants with the various infection types in table 6. Of the highly susceptible varieties Strubes Dickkopf, Heines glatter Teverson, Ackermanns Bayernkonig and Rimpaus fruher Bastardweizen we have listed results only of Strubes Dickkopf and Rimpaus Bastard. They show sufficiently well that no differences in infection type result for susceptible varieties from differing temperatures, as the highest type 4 was regularly observed at all temperatures.

The results of the preceding tables can be summarized to this extent that all resistant varieties, i.e. varieties that seem resistant at a normal temperature of around 20°C become susceptible to a greater or lesser degree at low temperatures. In order to gain a perspective of the test results we have calculated the average infection type from data contained in tables 5 and 6, giving the value of -1 to type i. We are perfectly aware of the fact that the frequent irregularities and cleavages are not apparent in the chosen average computation. In order to show especially marked occurrence of unequal infection types within the same test series, we have set those average values in brackets. Besides, we have included in table 7 results of some susceptible varieties not listed in tables 5 and 6.

The computation of average infection types contained in table 7 first of all shows a complete agreement with the behavior at temperatures of 8-20°C as far as the susceptible varieties Ackermanns Bayernkonig, Heines glatter Teverson, Rimpaus fruher Bastard and Strubes Dickkopf are concerned. The two first mentioned varieties suffered a weak decrease in infection type and a deterioration of infective success when the temperature was increased from 18-20 to 20-22°C.

Of the varieties more or less resistant at temperatures of about 20°C the following showed a marked increase in rust susceptibility already at 14-16°C: Aurore, Svalofs Panzer III, Lembkes Obotriten, Kettes Schlossweizen, Salzmunder Standard, Svalofs Kronenweizen and Kraffts Dickkopf. In this connection finer differences can be noted between the individual varieties, as revealed by the preceding table. If the infective tests are conducted at an even lower temperature (8-12°C), we usually get a further increase in rust susceptibility. Only Aurore and Salmunder Standardweizen fail to reveal a further elevation of the average infection type at the transfer from 14-16 to 8-12°C.

P.S.G. Hertha Weizen shows only an unimportant increase in susceptibility at infection tests at 14-16°C, while the transfer to temperatures of 8-12°C causes a very marked elevation.

Heines Kolben-Weizen and v. Rumkers Sommerdickkopf also show increased susceptibility at lowered temperatures, but even at 8-12°C there is still a considerable resistance. All in all, the results with the two just mentioned varieties agree in principle with the other resistant strains.

An exception seems to be Carstens Dickkopf V, in that the highest relative infection type was observed at 18-20°C. This result calls for a repetition, which however was not possible in view of the advanced season. It is conspicuous that on the average only the resistant type was seen at 14-16°C and 8-12°C, while the test series at 18-20°C resulted in a considerably higher susceptibility.

The statistical test data chosen in tables 5-7 naturally did not allow the ennumeration of the manifold details which also are of value in evaluating the different varietal behavior. We must limit ourselves to the more detailed discussion of only a few varieties.

Heines fruher Kolben, inoculated on 9 March 1929.

Findings on 21 March: at 20-22°C predominantly neither discoloration nor pustule formation, only quite isolated leaves with severe necrosis and very meager pustule eruption. At 14-16°C predominantly leaves with small necrotic spots, beside isolated leaves with very severe necrosis; leaves without successful infection are very rare. At 8-12°C almost all leaves have yellow discoloration, similarly to those of susceptible varieties. Some leaves also show severe necrosis.

Findings on 25 March: At 20-22° the percentage of leaves with pustule formation is extremely small. An additional small amount of leaves has sharply delineated necrotic spots; the overwhelming majority is, as before, devoid of any infection. At 14-16°C the infection is slightly better, but still unimportant. Still, the number of leaves with type 0 compared to type i has increased considerably, while the number of leaves with pustule eruption is still small. At 8-12°C half of the leaves show pustule eruptions with infection types 1-4. The remaining leaves reveal strongly marked spots, some with very severe necrosis. Leaves without infection (type i) are completely lacking.

P.S.G. Hertha Weizen, inoculated on 5 April 1929.

Findings on 15 April: at 20°C almost all leaves without infection, only a few leaves show isolated small, yellow spots. At 14-16°C all leaves are stained yellow, at times with necrotic spots. At 8-12°C all leaves are colored uniformly and weakly over the entire leaf surface.

Findings on 21 April: at 20°C the majority of leaves are healthy, a few have small chlorotic spots, an additional fraction shows partial discoloration of the inoculated leaf surface with weak pustule affliction. At 14-16°C a considerable increase in infection is noted. All plants show either discoloration or pustule eruption. The majority of plants have discoloration and necrosis; about one third show pustule eruption ranging from infection type 1 to 4; infection type 4 also is distinctly present. At 8-12°C (observation on 24 April) almost all plants reveal more or less distinct pustule eruption with strong predominance of the higher infection types (3 and 4).

Lembkes Obotriten-Weizen, inoculated on 5 April 1929.

Findings on 15 April: at 20°C infection is absent from almost all plants. At 14-16°C all leaves show uniformly strong yellow discoloration, at 8-12°C almost all plants have uniformly weak yellow discoloration extending over the entire leaf surface.

Findings on 21 April: at 20°C a few infections (types 0 and 3), almost all plants without infection. At 14-16°C all leaves with severe pustule eruption (types 3-4). At 8-12°C (reading of 24 April) all leaves with the strongest pustule eruption without discoloration (type 4).

The details just reported also show that infection at lower temperatures is considerably more successful than at higher ones; if we compare the different varieties to determine the manner in which temperature depression increases infective success, then a few differences become apparent. In certain varieties, as Salzmunder Standardweizen, the maximal rust susceptibility is reached already at 14-16°C. In others, as P.S.G. Hertha Weizen and Svalofs Kronenweizen it takes an additional temperature depression to 8-12°C to obtain highest incidence of rust.

It follows that we can observe a quite different sequence in the susceptibility of the individual varieties, depending on the temperature at which the tests were conducted. Just how marked these differences are can be seen from the summary on the reverse side in which not only the numerical values from tables 5-7 are included, but consideration has also been given to other observations and details which we are unable to discuss due to shortage of space.

Above tabulation (table 8, page 239) shows quite distinctly that resistance is conditioned by temperature. The question whether a variety is resistant or susceptible can be answered quite variously depending on the temperature used. There are varieties, as for example Heines Kolben-Weizen and v. Rumkes fruher Sommerdickkopf which still maintain a highly resistant character at low temperatures of 8-12°C, while other varieties are resistant only at high temperatures and highly susceptible at low ones. Perhaps it would therefore be practicable to introduce the concept of absolute and relative resistance for the diverse

degrees of ability to resist, whereby we would designate those varieties as absolutely resistant which are so at low temperatures as well as high ones, but more so at higher temperatures. Relatively resistant are those varieties which are distinctly resistant at 20°C, but susceptible or highly susceptible at low temperatures or partly already at medium temperatures.

The recognition that thermal differences of only a few degrees influence rust susceptibility to the marked extent observed is of fundamental importance from several viewpoints. It shows first of all that it is impossible to test varietal behavior against stripe rust in the same simple manner by greenhouse tests as in other types of rust, e.g. brown wheat rust or crown rust, which we have also tested on a large scale; with those there is not a trace of such a dependency on external factors as is the case with stripe rust. On the basis of above results there can be no doubt that the testing of resistance or susceptibility of wheat varieties to stripe rust requires simultaneous execution of the tests at different temperatures, in order to recognize the absolute or relative resistance of these varieties. It will be the mission of further examinations to work out detailed test methods for the determination of resistance to stripe rust, with consideration of thermal conditions.

From other viewpoints, too, the recognition of the importance of temperature for the susceptibility of wheat varieties to stripe rust represents an advance. If we scan the literature for the scattered references to the varietal behavior toward stripe rust, we sometimes meet with remarkable contradictions. One of the most prominent examples of this kind is presented by the Schwedischer Panzerweizen which has shown itself in some years and certain localities as resistant, in others as susceptible. Of course we can think here that this shift may be ascribed to the occurrence of biotypes of stripe rust. On the other hand our observations show that in principle this variety must reveal unequal occurrence of stripe rust under different thermal conditions, since it is resistant at higher temperatures and highly susceptible at lower ones. An agreement with this view can be found in the data of Schaffnit and Rump (26,27) to the effect that the severe occurrence of stripe rust on Panzerweizen reported by these researchers took place in May and June 1923 at low temperatures; at least the average temperatures for those months are reported at 10 or 11°C. The fact that the yield of the Panzerweizen has suffered considerably by stripe rust in several rust years is, to a certain extent, in conflict with our observations which show only infection type 3 and not type 4 at the lowest temperatures used, 8-12°C. It seems necessary to mention the possibility that under certain conditions type 3 may cause more damage than type 4. Types 3 and 4 may show identically severe pustule affliction; they differ only in the circumstance that type 3 has stronger discoloration leading to necrosis, while in type 4 the leaf remains mainly green. If we designate type 4 as the type of maximal susceptibility on the basis of greenhouse observations, we also involuntarily connect this idea with that of maximal damage. Whether this is correct seems still questionable, for type 3 shows considerably stronger discoloration, at times already necrosis, while in type 4 the leaf remains green, therefore functional. Damage may therefore be more extensive in type 3 than in type 4. In this case the occurrence of stripe rust on such a variety as Panzerweizen would be especially dangerous, and the severe harvest losses of precisely this wheat strain would thus be explained. The preceding discussion shows how

careful one must be not only in the evaluation of the question of resistance, but also in answering the question of how rust damage may lead to severe harvest losses. It is often conspicuous that susceptible varieties such as Strubes Dickkopf, in spite of severe rust affliction nevertheless yield a generous harvest, while varieties with an otherwise resistant type may go to waste to a stronger degree if they are badly afflicted under certain climatic conditions.

In any case, to date there has been no need to attribute the multiform development of rust epidemics on certain varieties in isolated years and certain localities to the presence of different biotypes. We have already mentioned above that we have to date no evidence of the existence of biotypes in stripe rust. Still, the question of stripe rust biotypes deserves attention now as before. However, the demonstration of biotypes seems especially difficult in this type of rust, as we have shown above how strongly rust appearance and varietal susceptibility are influenced by external circumstances, especially by temperature. We shall progress in the problem of biotypes only if the question of temperature and all other accessory conditions arrives at an unobjectionable answer. To repeat, we consider above all the virulence of the spores, the uniformity of inoculation and the amount of applied spores as the primary accessory conditions.

The question of biotypes is compounded by the previously mentioned occurrence of cleavage. If we read the individual detailed results contained in tables A and B, 2, 5 and 6, we frequently find that all possible infection types are present in the same test series. By way of change in test conditions we can shift the types in this or that respect and under certain conditions we can even consolidate them. By this action the question of how we should evaluate the simultaneous appearance of different infection types is compounded with a great uncertainty which must first be clarified before the question of biotypes can be approached. It should be noted again that our own tests were conducted with stripe rust material which had been obtained by repeated superinoculation from isolated pustules, negating the probability of work with a mixture of biotypes.

Nor should the deviating results of the greenhouse tests by Hungerford and Owens (18) mentioned by us be attributed to a conclusion that different biotypes of stripe rust were utilized by those authors and by us. In table 9 we list a short summary of infective results with those varieties that were tested for stripe rust by Hungerford and Owens as well as by us.

A comparison shows that the number of infections attained by Hungerford and Owens is relatively small, and that the infection types observed by these researchers fluctuate between 0 and 4, while we usually found the highest infection type 4 in all tested varieties. In our opinion the observations of Hungerford and Owens do not point to the presence of a deviating biotype. The results are rather to be explained by the circumstance that these researchers were not fully familiar with the infective technique of stripe rust tests. They had tested a total of 92 varieties in the greenhouse, without attaining completely successful infection with any variety. If, for instance, in the tests tabulated above of 30 plants 2 revealed infection type 4 and the remain-

der were not even infected, this tends to support the view that the infective conditions were objectionable. Just how little Hungerford and Owens (18) recognized the influence of external factors, especially that of thermal conditions, can be seen from the fact that they have not even given any data on them. They limit themselves to the generalization that all tests were conducted in the same manner as those of Stakman and Piemeisel (30) with black rust. If we refer to the test data of these authors, we see that they worked primarily with higher temperatures. Thus there is little doubt but that the inadequate infective results of Hungerford and Owens (18) are to be attributed to the neglect of thermal influence, and that excessively high temperatures probably were used also in connection with the cultivation of spore material.—

The test results recounted in this chapter suffice as proof that temperature plays a predominant role in the question of varietal susceptibility to stripe rust. We have repeatedly pointed out that the other test conditions also must be considered under all circumstances. We shall also briefly discuss the question of humidity. Naturally it is very difficult to maintain uniform humidity adjustments in greenhouses held at different temperatures, since the relative external humidity somehow influences the humidity within the greenhouse, especially when it is aired. Since the possibility must be taken into account that humidity may considerably influence rust appearance, we have regularly measured the relative humidit_ by means of an aspiration psychrometer. The relative humidity in the hot house fluctuated around 75% (50-90%), in the middle house around 80% (60-90%), in the cold house around 87% (80-95%). In order to determine whether the just mentioned fluctuations in relative humidity materially influence rust appearance and varietal susceptibility, test were conducted so that one part of the plants were allowed to stand freely on moist ground peat following the customary 3-day covered period, while the other half was kept at nearly 100% relative humidity under cover of light glass jars which were briefly aired daily to insure a supply of carbonic acid. In this connection the tests were further diversified in that the airing was done for shorter and longer durations. Table 6 (page 235) shows part of these tests in which the same varieties were subjected to comparison in the hot house at 73 and 100% humidity, in the middle house at 79 and 100%, and in the cold house at 87 and 100%. No differences in infective results were noted, supporting the conclusion that fluctuations in humidity recorded during our thermal tests did not decide the infective results, meaning that our conclusions on the significance of temperature for varietal behavior are above reproof.

This does not mean, however, that humidity has no influence whatever. If we keep the inoculated plants in the usual manner first under jars at 100% relative humidity and then place the pots , not on moist ground peat, but on a dry concrete surface, we can indeed note a decrease in infective success. Similarly we have previously pointed out (Gassner and Straib, page 615) that temporary covering of the plants at the time of pustule eruption can increase infection. However, the humid conditions in the discussed varietal tests at different temperatures (tables 5 and 6) were always so high that no disturbances occurred. Still, the lastly recounted observations show that the humidity must be chosen rather too high than too low in order to achieve optimal success in infection. The influence of insufficient humidity is slightly different for each variety. The relatively strongest reduction in pustule eruption due to inadequate humidity is noted in the resistant varieties.

While our tests with stripe rust have shown that the resistance of the varieties increases with climbing temperatures, tests with Puccinia triticina and Puccinia coronifera have demonstrated extensive independence of temperature in varietal behavior. Conversely, Puccinia graminis also seems to have a certain predisposition to temperature, in the question of varieties. However, the rule here is entirely different, in that the degree of resistance of Puccinia graminis does not increase with higher temperatures, but decreases, and at temperatures over 20°C higher rust types are noted on the same varieties than at lower temperatures.

The preceding conclusions about the multiform influence of temperature on susceptibility to the various types of rust are also of interest to the extent that they easily explain the divergent occurrence of the various rust types in the field during a given season as well as in countries of different climates. Black rust is observed primarily in late summer and in countries with hot summers, while stripe rust prefers spring and early summer, as well as countries with a moderate climate. Brown rust and crown rust are able to infect their hosts in all seasons and countries whenever the development of the host plants themselves is possible. If these rust types also as a rule appear in summer in these parts, this circumstances is due to the factor of wintering, but hardly to climatic influences, since the varietal susceptibility of the plants is little influenced by thermal conditions.

Comparative field observations.

Greenhouse tests of varietal behavior against stripe rust have a practical value for plant cultivation and seeding only if the rust reaction determined experimentally agrees with rust affliction in the field. Only in this case can conclusions be reached from the results of artificial infection, to be applied to varietal susceptibility in the field. We must therefore by all means approach the question to which extent the greenhouse tests discussed in the foregoing chapters agree with rust appearance in the field. We are supported herein primarily by our field observations in Schlanstedt, where a regular and severe occurrence of stripe rust had taken place in 1926 and 1927. In this connection it should be stressed again that the strain of Puccinia glumarum used in our greenhouse tests also originated in Schlanstedt. We selected this strain on purpose in order to effect better comparison between greenhouse and field tests.

Field observations for the evaluation of actual varietal susceptibility are only usable if, as we have already stated in the introduction, the distribution of rust is very uniform and general, so that local differences and coincidences have no influence on the results. During the obsergations of the year 1927, on which this report is mainly based, this condition was met, as is also evident from the disclosure of the director of seed cultivation, Bonne (5) at Schlanstedt.

In order to conduct successful field observations also in those years in which no general rust occurrence takes place, it is recommended to make arrangements for uniform infection by means of the intermingling of uredo-bearing plants or by artificial cultivation of spores, as was done successfully by

Gassner (10,11) in 1907-1910, and subsequently also by other researchers, e.g. Hungerford and Owens (18).

The determination of rust affliction in the field was conducted in the customary way, i.e. based on severity of involvement. The valuation of rust intensity was done with the designations 0, + to ++++, where 0 equals rust-free, + is very weak, ++ is weak, +++ is strong and ++++ is very strong. + corresponds to 2, ++ to 3-4, +++ to 5-6 and ++++ to 7-8 of the eight-part scale of rust intensity suggested some time ago by Gassner (10,12).

At the valuation of rust severity the stress was laid on the number and distribution of formed pustules. It suggested itself to determine and consider the infection type in a similar manner as in the greenhouse tests, in addition to severity of rust affliction. This, however, has proved to be difficult to accomplish, above all because many varieties which initially show severe rust involvement without any discoloration, i.e. are classified under infection type 4, in later development often reveal necrotic manifestations which make the evaluation of infection types uncertain. Even in the greenhouse the infection type can be utilized as a standard only within a certain test duration; it loses its worth if the duration is extended unreasonably and the leaves begin to die off naturally. Still, a certain amount of consideration for infection types may be used in field tests; however, care should be taken to recognize that possibly appearing discoloration may be a sign of the start of a severe and complete infection as well as a sign of development of a resistant infection type. In field tests namely we never know when the infection has taken place, and therefore cannot easily judge from existing discoloration whether or not there will be a formation of pustules. Even in susceptible varieties the disease may be limited to necrotic discolorations if the weather turns dry and hot.

For this reason we have first of all valuated the degree of affliction. It is known that determination of rust appearance always has a subjective character, and that errors can not always be avoided therein. This may entail only the growth of new leaves shortly prior to the reading, which in view of the long incubation may not show any sign of infection as yet. In such cases too low an appraisal may be fixed on rust affliction, which is especially annoying if varieties in different stadia of development are to be compared. Concerning further details about sources of error in field tests, the reader is referred to earlier papers by Gassner (10,11,12).

Thanks to the kindness of the firm of Strube our observations at Schlanstedt covered the extensive assortment planted at Schlanstedt as well as varietal tests conducted there locally. The observations made in the assortment are contained in tables A and B (last column) at the end of this paper, rendering a direct comparison possible between these observations and the results of the greenhouse tests.

This comparison in many places reveals a favorable consonance between field observations and greenhouse tests. Severe rust involvement in the field often is parallel to a high infection type in the greenhouse. But we also have a good number of cases in which the highest infection type 4 was noted in the greenhouse, while only a weak rust affliction was seen in the assortment test.

Conversely, all varieties that showed severe involvement in the field also yielded the highest infection type in the greenhouse. Furthermore, it rarely happens that varieties with a resistant type in the greenhouse become strongly afflicted in the field. Varieties immune in the greenhouse are also free of rust in the field.

In evaluating the comparisons just made it should be remembered that the greenhouse tests shown in tables A and B were conducted at the relatively high temperatures around 20°C, and that additional differences between individual test series were present in the form of temperature and light conditions. After detailed proof was submitted in the preceding chapter to the effect that the temperature is of paramount importance for the results of infective tests in the greenhouse, we cannot expect that the results of greenhouse and field tests summarized in tables A and B would allow the unequivocal reply to the question to which extent we may apply greenhouse results to the expected resistance in the field. To this is added the circumstance that the beds of 1 qm in the assortment tests do not appear large enough, without repetition, to allow the determination of the finer differences in rust behavior with sufficient precision and certainty. For the sake of completeness it should be recalled that rust affliction had reached its apex at the time of observation on 28 June 1927. The majority of winter wheat varieties were blooming at the time, a small portion started to bloom or had already done so. The summer wheat varieties of the assortment had shoots at the time but did not bloom as yet.

Due to the shortcomings already mentioned which hampered the observations at the assortment, we have put the stress on the varietal examinations at Schlanstedt. The tests were conducted on 50 qm parcels and repeated 4 times. Readings were taken, for the sake of certainty, on three different days, on 18 May, 16 and 28 June 1927. The winter wheat plants had an average height of 40 cm and started to form the stalk. On 16 June they were immediately prior to appearance of the ear. On 28 June most of the varieties were in bloom, only the Salzmunder Standard had not finished sprouting. Only one observation on 2 July 1927 could be made in connection with the summer wheat; at this time most of the varieties commenced to bloom. All tests therefore were quite favorable for the evaluation of rust susceptibility, because they were conducted four times, and especially since they were situated at an exceptionally moist spot of an old swamp where stripe rust was prevalent and regular. According to the director of seed growing, Bonne (5), the occurrence of stripe rust in these varietal tests was already quite severe at the end of April. Our own rust valuation agrees with the rust degrees determined by Bonne and published elsewhere (5). Unfortunately a direct comparison is impossible since Bonne did not publish his observations with varietal designations but under cover numbers. On the other hand we can refer to Bonne's paper for weather conditions during the time of observation and other test conditions.

We limit ourselves in the reported field observations to the summer of 1927 which was distinguished by regular and severe incidence of rust at Schlanstedt. These observations of 1927 are in relatively favorable agreement with the rust behavior of the same varieties at Schlanstedt in other years. The second of the present authors had the opportunity to test most of the pertinent varieties at Giessen in 1925 and 1926. Here too the varietal reaction was principally identical. The careful field observations by Schaffnit and Rump (27) are also

in consonance with our findings of 1927, all of which seems to justify the use of Schlanstedt's varietal behavior of the year 1927 as the yardstick of stripe rust susceptibility of the observed varieties. We did not consider the older examinations by Kirchner (19) because it cannot be determined with certainty if the varieties listed by Kirchner are still identical with modern strains.

The following table 10 (page 252) shows the results of our field observations together with the findings of rust infection tests in the greenhouse conducted at different temperatures, already discussed in detail in the preceding chapter. The testing of some varieties at low temperatures is lacking. Generally it is possible on hand of reported results to make easy comparisons between rust appearance in the field and varietal resistance at different greenhouse temperatures.

On the basis of the summary in table 10 we can devide the different varieties according to their reaction to stripe rust into following groups:

1. Varieties highly susceptible in the greenhouse and also highly susceptible or even more so in the field:

Beseler Dickkopf III
Hohenheimer Dickkopf
Hornings Dickkopf
Lohnauer begraunter Dickkopf
Strubes Dickkopf
Hohenheimer Sommerweizen 25 f.
Aereboe-Weizen
Peragis-Sommerweizen
Mahndorfer Dickkopf
Bethges Sommerweizen Stamm 19
Dippes Bordeaux
Rimpaus roter Schlanstedter
Strubes roter Schlanstedter.

2. Varieties showing a more or less high resistance in the field and in the greenhouse, especially at lower temperatures:

Carstens Dickkopf V
Kraffts Dickkopf
P.S.G. Hertha Weizen
Strubes Neuzuchtung 3186
Heines Kolben
Janetzkis fruher Sommerweizen.

In connection with above varieties, greenhouse observations and field resistance were parallel. The remaining varieties reveal irregularities, however:

Lembkes Obotriten-Weizen shows a fluctuating behavior, being almost immune in the greenhouse at high temperatures, but highly susceptible at 8-12°C

and 14-16°C. The field tests also reveal inconsistencies in affliction at different times.

Burckners Dickkopf, Raeckes Sieghart and Rimpaus Bastard are resistant in the field, highly susceptible in the greenhouse even at 20°C.

Strubes General v. Stocken is less susceptible in the greenhouse only at temperatures above 20°C, highly susceptible below 20°C; it was only weakly susceptible in the field.

Svalofs Panzerweizen cannot be compared directly in field and greenhouse tests, since the field tests covered Svalofs Panzer II and temperature-greenhouse tests Svalofs Panzer III. As far as our previous greenhouse tests are concerned, no apprecia'le differences between the actions of Panzer II and Panzer III were found (cf. also table A with table 5). Under this assumption Svalofs Panzerweizen is first weakly, then strongly susceptible in the field, in the greenhouse almost immune at high temperatures, moderately susceptible at low ones.

Nordharzer Burgweizen, a descendant of Svalofs Panzerweizen, reacts identically.

Werthers Ettersberger is medium susceptible in the field, in the greenhouse moderately resistant at temperatures above 20°C, at 18-20°C highly susceptible.

Hornings Sommerweizen "grune Dame" is resistant in the field, but already at 18-20°C highly susceptible in the greenhouse. It should be stressed that the occurrence of rust in the field was partly extraordinarily severe in connection with the other summer varieties.

Stadlers weisspelziger Sommerweizen is weakly susceptible in the field, in the greenhouse already strongly affected at 18-20°C.

v. Rumkers fruher Sommerdickkopf shows irregularities in rust appearance in the field. It was resistant in the greenhouse at all temperatures, nearly immune at temperatures above 16°C; however, one origin revealed itself as strongly susceptible also in the greenhouse (see table B, page 274). As is evident from table B at the end of this paper, it was highly resistant in the assortment at Schlanstedt in 1927, but was highly susceptible in the varietal test 1927, as listed in the table on the reverse, resulting in a strong contradiction. A confusion of varieties certainly was not involved, since especially the Sommerdickkopf is easily recognized and was identifi. by us as such. How to explain the contradiction in the field observations between varietal test and assortment cannot be decided. The conditions for severe rust occurrence doubtless were more favorable in the varietal test. But not even this difference seems adequate to explain the strongly opposed behavior, especially since the other varieties showed nearly the same reaction in the assortment test and the varietal experiments.

Thus, while we have a relatively good accord in rust behavior in the

majority of the tested varieties between field observations and greenhouse tests, the lastly mentioned varieties reveal irregularities, pointing to the fact that despite the consideration of temperature we do not know all the factors today which are decisive in the incidence of stripe rust and the development of severe infections. Indeed, there are differences between field plants and greenhouse plants. Greenhouse tests are conducted almost exclusively with germinal plants in view of the technical difficulties inherent in cultivation and further care of grain plants under greenhouse conditions. It may be presumed that the leaves of older plants of some varieties react differently, especially since the metabolism of these plants is unquestionably divergent.

Furthermore, it must be considered that we cannot adequately imitate the natural moisture and temperature conditions in greenhouse tests. The considerable fluctuations in temperature occurring in April, May and June in the field, usually accompanied by corresponding parallel differences in humidity, cannot be duplicated under greenhouse conditions. It should also be pointed out again that the inoculative technique in the artificial infective attempt also deviates from natural spore dissemination. During spore application in the artificial infective attempt the wax layer of the leaves is rubbed off, while natural germination occurs on the wax layer. These disturbances may only be avoided if a successful inoculative method is perfected which makes rubbing unnecessary. It shall be one of the next missions to accomplish comparative varietal tests with the conventional method of inoculation on one hand, and careful application of spores, corresponding to natural conditions, on the other, in order to recognize the extent to which the discussed method can influence the results of varietal examinations. So far we did not succeed, or did not obtain sufficient uniformity, in obtaining satisfactory infections by the spraying of spore suspensions onto previously moistened leaves.

Although we have not been able to conduct greenhouse experiments in such a manner that such tests would automatically foretell the varietal resistance to stripe rust in the field, on the other hand the results nevertheless seem to be of importance to the breeding of resistant varieties. A considerable number of varieties have shown manifestations which we must explain as inherited cleavages. It must be granted that the relationship of these cleavages is not constant, and that we must be very careful, especially in the evaluation of tests at higher temperatures, because the number of plants with a resistant type is always considerably smaller at low temperatures, or even lacking altogether. On the other hand, cleavages at low temperatures, at which the general infective conditions are more favorable, seem to have practical value for plant cultivation. There should be no doubt that systematic dissociation of groups according to rust resistance has not been accomplished heretofore, or only incompletely so, because field observations are not well suited for this purpose. Initially it must of course be determined to which extent those plants that proved themselves resistant under optimal infective conditions in greenhouse tests, retain this property under general growth conditions in the field, and how the offshoots of these plants will behave in greenhouse and field tests. These tests have been started by us and are progressing. Such a resistance test is of particular value for the isolation of resistant lines following hybridization. In this respect Biffen (4), Nilsson-Ehle (24), Marryat (22), Vavilov (32,33) and Armstrong (1) have already conducted valuable

research, in which they utilize field tests for rust observation. We shall naturally arrive at a much better classification and description of rust behavior if we use simultaneous artificial infection tests in the greenhouse, especially since varieties which are immune or highly resistant in the greenhouse almost without exception show the same reaction in the field. In this direction the preceding test results do not seem worthless, despite the difficulties. In view of the peculiar behavior of stripe rust we did not expect from the start that the tests would lead to a final result; we must also consider that difficulties were also met by the American researchers who primarily dealt with black rust and brown rust, i.e. rust types whose infective reaction is much simpler. They also experienced difficulties in their attempts to apply greenhouse test results to the practice. In spite of these difficulties, unquestionable practical advances have nevertheless been achieved here. The deeper the insight gained into the peculiar infective conditions of stripe rust, the sooner we shall arrive at concrete results in connection with this type of rust.